APPENDIX A

GROUND RULES & ASSUMPTIONS

AND

LESSONS LEARNED

The following are specific examples of types of ground rules & assumptions, and lessons learned that have been previously utilized and developed by various programs. They have been developed to address various RCM program factors such as minimizing cost of performing the RCM, ensuring a consistent analysis approach, assisting in future reviews of the analysis, etc. They are provided for general consideration and may be used verbatim or modified as required for each program. The examples are by no means a complete list of issues to be addressed.

1. Ground Rules & Assumptions

A. FMECA/RCM

(1) Combining Failure Modes. Similar failure modes for different components may be combined in instances where more than one component failure results in the same Local Effects, Next Higher Effects, End Effects, detection method, and failure consequences. The affected components shall be listed in the memo field with the EFM listing a reference to the memo field. Likewise, different failure modes for one component may be combined if Local Effects, Next Higher Effects, End Effects, detection method, failure consequences, and any resulting PM tasks are the same.

(2) Theoretical Failure Modes. For certain components, EFMs that are determined not credible (i.e. due to system design, materials or other factors, no failure of a device can be established) the EFM shall be noted as “Theoretical EFM”. However, normally non-credible failure modes are not listed on the FMECA. The only reason to list them is to show that an obvious failure mode was considered and found to be not credible. It may not be necessary to list all failure modes.

(3) Hidden Failures. Effects for hidden failures should assume that the failure which causes the hidden failure to become evident has occurred. For example, the normal function of “landing gear extension” has failed which then in turn makes the failure of the “emergency landing gear extension” function evident.

(4) Secondary damage. When performing the FMECA, the effects of secondary damage should be considered. For example, a bleed air duct ruptures and the resulting hot air damages surrounding structure, hydraulic lines, fuel lines, etc.

(5) Normal Duties. The programs definition of “normal duties” must be clear. For example, determine whether the Naval Air Training and Operating Procedures Standardization (NATOPS) procedures are considered aircrew normal duties for failure detection and evidence questions. (Note: The T-45 program elects to consider NATOPS procedures not a part of aircrew normal duties.)

(6) Prioritization of the Failure Modes. The AV-8B program uses the following table, TABLE 1, to assist in the prioritization of their RCM effort. RCM typically is not performed on failure modes that fall under the acceptable risk category.

RCM HAZARD RISK ASSESSMENT

FREQUENCY / CRITICALITY	FREQUENT (A) $> 1x10^{-3}$ > 1 per 1,000 hours	PROBABLE (B) $> 1x10^{-4}$ > 1 per 10,000 hours	OCCASIONAL (C) $> 1x10^{-5}$ > 1 per 100,000 hours	REMOTE (D) $> 1x10^{-6}$ > 1 per 1,000,000 hours	IMPROBABLE (E) $< 1x10^{-6}$ < 1 per 1,000,000 hours
CATASTROPHIC (I) DEATH LOSS OF A/C OR SYSTEM SYSTEM OR PROPERTY DAMAGE > $1,000,000	1 HIGH	2 HIGH	4 HIGH	8 MED	12 ACCEPT
CRITICAL (II) SEVERE INJURY / PARTIAL DISABILITY IMMEDIATE PILOT ACTION REQUIRED TO PREVENT CAT I RESULTING IN SAFETY MISSION ABORT SYSTEM OR PROPERTY DAMAGE > $200,000	3 HIGH	5 HIGH	6 MED	10 LOW	15 ACCEPT
MARGINAL (III) MINOR INJURY/ 5 OR MORE LOST WORK DAYS MISSION LOSS OR DEGRADATION SYSTEM OR PROPERTY DAMAGE > $10,000	7 MED	9 MED	11 LOW	14 ACCEPT	17 ACCEPT
NEGLIGIBLE (IV) LESS THAN MINOR INJURY CONTINUE MISSION WITH MINIMAL RISK SYSTEM OR PROPERTY DAMAGE < $10,000	13 ACCEPT	16 ACCEPT	18 ACCEPT	19 ACCEPT	20 ACCEPT

RISK LEVELS:

- HIGH — MANDATORY CORRECTION FOR HAZARD ELIMIINATION OR CONTROL. REQUIRES PROGRAM MANAGEMENT APPROVAL FOR RISK ACCEPTANCE.
- LOW — INFORM HARRIER PROGRAM MANAGEMENT AND SSWG OF RISK.
- MED — REQUIRES MANAGEMENT REVIEW FOR RISK ACCEPTANCE. HARRIER PROGRAM MANAGEMENT AND SSWG CONCURRENCE.
- ACCEPT — ACCEPTABLE RISK. REVIEW AS DESIGN MATURES.

TABLE 1. RCM Hazard Risk Assessment

B. SI Selection

(1) Definition of "High Failure Rate or Consumption of Resources". The following are examples of specific criteria related to failure mode SC and MTBFs used when answering the question "Is failure rate or consumption of resources high?" of the FSI/SSI selection logic diagram:

T-45		AV-8B	
SC III	MTBF < 100,000 FHs	SC III	MTBF < 6,000 FHs
SC IV	MTBF < 10,000 FHs	SC IV	MTBF < 3,000 FHs

C. Flight Assumptions

(1) Definition of flight phases: T-45 uses from take-off roll to engine shutdown as the flight phase. E-6 uses from wheels off the ground to wheels on the ground as the flight phase. AV-8B uses from engine start to engine shutdown as the flight phase.

(2) Definition of mission phases: The following are examples of mission phases that various programs use when performing a FMECA:

(a) Taxi

(b) Take-Off

(c) Landing

(d) Climb

(e) Cruise

(f) Flight

(g) Descent

(h) Maintenance

(I) Emergency

(j) Mission

(k) In-flight refueling

D. Systems Interface - Analysis of wiring, tubing, etc.: One method, as is being done on the E-2 program, of analyzing wiring, tubing, etc. is to divide the aircraft into zones and identify functions, functional failures, and engineering failure modes for each zone. Another consideration is whether wiring, tubing, etc. should be analyzed as separate systems or components of another system. The Naval Aerospace Vehicle Wiring Action Group (NAVWAG) RCM implementation guide provides further guidance.

E. Default Values

(1) Acceptable probability of failure. The following is an example of values the T-45 and E-6 program are using.

Severity Classification	Pacc
I	.000001
II	.0001
III	.01
IV	.1

(2) Cost benefit analysis factors. The following are several cost benefit analysis factors that should have default values assigned. Some may vary from program to program.

Labor rate:	O or I organic - $25/hr D organic - $50-$100/hr
Aircraft cost:	Varies with program
Fleet size:	Varies with program
Service life:	Varies with program

Utilization rates: Varies with each program, however the following are example values (Flight-hour per month (FH/month)):

T-45 - 60FH/month
AV-8B - 30FH/month
E-6 - 100FH/month

(3) Potential to functional failure intervals:

T-45 - One aircraft lifetime (14,400FH) for crack EFMs due to contractual requirements.

AV-8B - One aircraft lifetime (6000FH) for crack EFMs due to contractual requirements where no crack growth analysis nor actual failure data exists.

(4) Structural inspection intervals: The following tables, TABLES 2, 3, and 4 are examples of rating factors which may be used to help establish structural inspection intervals for fatigue, environmental, and accidental damage failure modes.

CPL SRF	Inspection Interval

1	1/4 CPL
2	1/3 CPL
3	1/3 CPL
4	1/2 CPL

TABLE 2. Fatigue Damage.

ED Average SRF	On-Condition Task Interval
1.0 - 2.0	7 Day
2.1 - 3.7	14 Day
3.8 - 4.0	56 Day

TABLE 3. Environmental Damage

AD Average SRF	On-Condition Task Interval
1.0 - 1.5	Daily/Turnaround
1.6 - 3.0	Phase/Zonal
3.1 - 4.0	Opportunity

TABLE 4. Accidental Damage

(5) Default On-Condition task intervals. The T-45 program uses, where a current effective PM task and no other data existed, the following method:

(a) Calculate the number of inspections, **n,** according to the methods presented in chapter 3 (paragraph 3.4.3).

(b) Multiply the existing task interval by **n** to determine the interval from potential to functional failure.

(c) The existing task interval is then documented in the analysis.

The following variation of this method, to refine the existing task interval, could be used if the probability of detecting a failure in one inspection, Θ, for the new task is expected to be different from the Θ for the existing task.

(a) Calculate n according to the methods presented in chapter 3 (paragraph 3.4.3) using Θ for the existing task.

(b) Multiply the existing task interval by n to determine the interval from potential to functional failure.

(c) Recalculate n using the expected Θ for the proposed task.

(d) Calculate a new task interval by dividing the interval from step 2 by the value of **n** from step 3.

(5) Default Beta (β) values for Weibull failure distribution analyses for the F-402 - Low cycle fatigue: β = 7.4

(6) Crack growth analysis variables:

AV-8B & T-45 - Initial flaw = 0.01 inch
AV-8B - Initial flaw for welds = 0.05 inch

AV-8B - Initial flaw for bolts = 0.005 inch

F. GFE/Common Equipment

(1) GFE/Common PM Requirements. The T-45 program used existing PM program requirements for GFE/Common equipment. The RCM analysis was performed only to the system interface for GFE/Common equipment. The E-6 program makes a value judgment as to whether the government or contractor would perform RCM analysis on GFE/Common equipment where no analysis exists.

(2) For components that are common among aircraft, an RCM analysis is sent to the directing authority for evaluation of wider application.

G. Directed PM

The T-45 program evaluates directed PM requirements on a case-by-case basis as to whether the PM tasks would be documented in the RCM analysis as is or re-analyzed. Differences resulting from the re-analysis are sent back to the directing authority for resolution.

H. RCM Process Tailoring

(1) Prior RCM logic required the analyst to stop after a task is determined to be applicable and effective. The T-45 program required a cursory review to determine if other applicable and effective tasks were more cost effective. The current RCM logic allows the analyst to continue the analysis and review additional tasks for applicability and effectiveness.

(2) The T-45 program did not require completion of AE task analysis if the RCM developed PM task was a Daily or Turnaround defaulted task.

(3) The AV-8B program identified strength and fatigue crack life and margin of safety cutoff values, based on testing and/or analyses, to limit the number of SSI Fleet Leader Sampling candidates.

I. Data Sources

(1) The T-45 program used two years of 3-M data for like equipment on AV-8B, A-4 and F-18 aircraft to calculate MTBFs.

(2) The E-6 program used ten years of 3-M data for the same equipment used on the EC-130Q for actuarial analysis.

(3) The P-3 program used 3-M data and I-level shop supplied data for RCM analysis of the oxygen panel mounted regulators.

(4) The AV-8B program used subcontractor/vendor environmental, strength and operational test-to-failure data for actuarial and degradation analyses on numerous components.

2. Lessons Learned

A. Leaking is defined as an effect and not a failure mode. A leak is the result of a crack or worn seal or some other mechanical failure. The mechanical failure is the failure mode.

B. Be specific when describing failure modes by identifying the specific hardware, part on/in the hardware as well as the mode description (e.g. fractured forward clevis).

C. Be specific on failure detection methods, identifying specific functions and location versus generic methods - e.g. cockpit fuel pressure warning lights vs. cockpit indications. Refer to the NATOPS manual for specific caution, warning, and advisory descriptions as well as other examples.

D. If a failure is noticeable in the normal course of flight or ground operations, then it is considered detectable for that associated phase of observation. The corresponding “Method of detection” will then be described in the FMECA. The method of detection can therefore in some cases involve observation of the “effects” of such a failure.

E. Experience has shown that failure modes are combined inappropriately when the consequences or effects of failure have not been properly considered.

F. Experience has shown that analysts, on occasion, combine functions inappropriately. For example, a landing gear actuator provides the functions of extending and retracting the landing gear. Failure of the actuator to extend has different consequences than failure to retract. Therefore, the two functions (extend and retract) of the landing gear actuator should not be combined.

G. Avoid use of “turnaround”, “daily”, “phase”, etc. in describing an inspection. Just describe the task and let the packaging determine the interval.

H. Minimize use of words “potential” and “eventual” when describing failure effects. These should only be used when the effect of the failure is not certain or immediate.

I. Task descriptions involving inspection for wear, free play, or other quantifiable limits shall state the limits or state where the quantifiable limits are documented.